EFFECT OF STARTER NITROGEN FERTILIZER ON NITROGEN FIXATION OF SOYBEANS IN THE NORTHERN GREAT PLAINS

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ABSTRACT

Environmental conditions at the time soybeans (*Glycine max* (L.) Merrill) are planted in the northern Great Plains are such that nitrogen (N) fixation may not occur immediately, therefore additions of N as starter fertilizer may increase initial growth of soybeans and possibly increase yield and quality. The objective of this study was to evaluate the response of soybeans to low rates of N applied at planting. A field experiment was established within a two-year corn (*Zea mays* L.) soybean rotation using a split-plot design with four replications. Whole plots were no-till (NT) and conventional tillage (CT) and the split plots were starter fertilizer (two sources x four rates) treatments. Nitrogen sources were either ammonium nitrate (AN) or urea (UR) each applied at 0, 8, 16, and 24 kg N ha^{-1}. Tillage treatments only affected biomass production for the R1 sampling dates for 2001 and 2002. Biomass production significantly increased with increasing N rate for all growth stages and years except for the R7 sampling in 2002. The R1 2000 sampling date was the only sampling date with a significant difference in biomass due to N source, with UR producing greater biomass compared to AN. Plant ureide concentration was significantly higher for UR compared to AN for the R1 sampling date for 2000 and 2002 with no response in 2001, possibly due to differences in planting dates. Tillage significantly affected ureide concentration at the R7 growth stage 2001 and 2002, with the NT treatments resulting in a higher ureide concentration compared to CT. Relative ureide content decreased with increasing N rate for the R1 sampling date in all years. In contrast biomass production increased with N application. This decrease in N fixation was not present for the R7 sampling date but the significant increase in biomass production was still present, possibly indicating the potential benefits of applying N fertilizer at planting in unfavorable environmental conditions.

INTRODUCTION

Over the past ten years soybean acreage in Minnesota, South Dakota and North Dakota has increased dramatically from 8,500 thousand acres in 1992 to 13,600 thousand acres in 2002, representing an increase of 40% (NASS, 1993 and 2003). This increase in soybean production coupled with the establishment of soybean processing centers in the region has caused producers to seek information to improve traditional management strategies. Because soybeans are a legume and have the ability to fix N, fertilization with N is not a common practice. Nitrogen fertilization has been evaluated by researchers as a method to improve protein levels in seed.

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The majority of this research has taken place in the southern portions of the Unites States with N application occurring in-season. Limited research has been performed evaluating the impact of low rates of N applied at planting on soybeans grown in the northern portion of the Unites States. The objective of this study was to evaluate the response of soybeans to low rates of N applied at planting. Soybean response will be determined by measuring biomass production, N concentration, and by estimating N fixation under varying N rates, sources and soil management practices in the northern Great Plains.

MATERIALS AND METHODS

A two year corn-soybean rotation experiment was established in the spring of 2000, at the Eastern South Dakota Soil and Water Research Farm near Brookings, SD. Soil types included a Barnes clay loam (fine-loamy, mixed, superactive, frigid Calcic Hapludolls), and a Vienna-Brookings complex (Vienna - fine-loamy, mixed, superactive, frigid Calcic Hapludolls; Brookings - fine-silty, mixed, superactive, frigid Aquic Hapludolls).

Pioneer variety 91B01 soybeans were seeded at a rate of 590,000 seeds ha^{-1}. Planting occurred on 22 May 2000, 30 May 2001 and 15 May 2002 with an 8 row JD 7200 planter. The experimental design consisted of a split-plot design with four replications. Whole plots were tillage (no-tillage (NT) and conventional tillage (CT)) and the split plots were fertilizer (source x rate) treatments. Conventional tillage was performed with a chisel plow in the fall of each year and seedbed repaired in the spring using a field cultivator. Crop cultivation was performed in early July of each year. Starter fertilizer treatments were placed in a 2 x 4 factorial arrangement with two N sources, either ammonium nitrate (AN) or urea (UR), each at four rates (0, 8, 16, and 24 kg N ha^{-1}). Phosphorus (P) and potassium (K) were applied at 112 kg ha^{-1} of 0-36-13 (N-P_2O_5-K_2O) to all experimental units. All starter fertilizer was applied at planting in a 2 X 2 band. Plots were 6 X 15 m with 0.76 m row spacing. Phenology data according to Ritchie et al. (1996) were recorded weekly from the first of June until the end of August.

Aboveground biomass sampling was performed at growth stage R1 and R7, by collecting 1 m of one row. Samples were dried for 120 h in a forced-air oven at 60^0 C, and then weighed to obtain dry matter production. Samples were ground to pass a 2 mm sieve. Total N concentration was determined on all samples using dry combustion (Schepers et al., 1989). Ureide concentration described by Patterson et al. (1981) and for nitrate concentration according to the method of Catalado et al. (1975) was determined on all samples. Relative abundance of ureide was expressed as ureide as a percentage of ureide plus nitrate ([ureide/(ureide + nitrate)]*100). Data analysis was performed using the Mixed procedure in SAS (SAS Institute, 1988), utilizing $\alpha = 0.10$.

RESULTS AND DISCUSSION

Plant Biomass

The tillage treatment only affected biomass production for the R1 sampling dates for 2001 and 2002, with CT having a higher average biomass compared to NT (Table 1). The higher biomass production for the CT treatment could be attributed to the slower emergence for the NT treatment compared to the CT treatment. Soil temperatures are traditionally lower under NT soil management, leading to slower emergence. The plants were able to overcome this initial delay in emergence so that biomass production at the R7 growth stage was not significantly different, although the NT treatment biomass production was slightly lower. The lack of a difference in tillage in 2000 can be attributed to the fact that the NT treatments were established in plots that were managed under CT until the spring of 2000 just prior to the start of this experiment.

There was a significant response to starter-N on biomass production for all sampling years and growth stages except for the R7 sampling for 2002 (Table 1). In general biomass production increased with N application compared to the no N treatment, these results are similar to Starling et al. (1998) who found that N applied at planting increase biomass at the R1 growth stage. The only sampling date that production did not increase is applied N was for the R1 2000 sampling where the 8 kg N ha^{-1} rate decreased yield compared to the no N treatment. This sampling date was also the only date with a significant difference in biomass due to N source (Table 1).

Table 1. Soybean biomass production collected at beginning bloom (R1) and beginning maturity (R7) treatment means by tillage, N rate and source, Brookings, SD 2000-2002.

	---Biomass, kg ha^{-1}---					
	2000		2001		2002	
Tillage	R1	R7	R1	R7	R1	R7
CT	921	5667	677	4960	661	4681
NT	907	5662	586	4720	478	4464
Pr > F	0.5983	0.9856	0.0814	0.1743	0.0104	0.4759
N Rate, kg N ha^{-1}	R1	R7	R1	R7	R1	R7
0	912	5530	580	4645	524	4702
8	864	5469	605	4675	552	4500
16	935	5862	662	4899	614	4649
24	944	5798	679	5139	588	4439
Pr > F	0.0778	0.0909	0.0012	0.0471	0.0857	0.1922
N Source	R1	R7	R1	R7	R1	R7
AN	893	5610	633	4925	571	4554
UR	935	5720	630	4754	568	4590
Pr > F	0.0739	0.3955	0.8480	0.2132	0.8923	0.7095

CT – conventional tillage; NT – no-tillage; AN – ammonium nitrate; UR – urea

Plant Nitrogen Fixation

The impact of N management on soybean N fixation was estimated by measuring total plant N, plant ureide and nitrate concentrations. Fixed N is transported in soybean plants in the form of ureide (Harper, 1987). Residual or fertilizer N is transported in soybean plants in the nitrate form. Relative ureide was calculated using ureide and nitrate concentration and can be utilized as a measure of N fixation according to Herridge and Peoples (1990). Plant ureide concentration was significantly higher for UR compared to AN for the R1 (beginning bloom) sampling date when planting occurred in mid May (2000 and 2002) compared to late May (2001). The planting date for the 2001 season was 30 May when soil temperatures were higher (16.2^{0}C at 15 cm) compared to the mid May planting date for 2000 and 2002 (22 and 15 May respectively) when soil temperatures were lower (12.2 and 8.5^{0}C at 15 cm respectively). Urea fertilizer must be transformed into the ammonium form before it can be taken-up by the plant

(Tisdale et al., 1993). Cooler soil conditions at the time of planting could have delayed this transformation, thus increasing the need to increase plant N fixation our results demonstrate an increased amount of ureide in the plant for plots fertilized with UR compared to the readily available AN source (Table 2). Ureide concentration at the R7 growth stage (beginning maturity) was significantly affected by tillage for the 2001 and 2002 growing season, with the NT treatments resulting in a higher ureide concentration compared to the CT (Table 2).

Relative ureide levels suggest a decrease in fixation with increasing amount of N applied regardless of N source or tillage practices for all three growing seasons for the R1 growth stage as indicated by the lack of a significant N source, tillage, two-way or three-way interaction. No significant N rate, N source, tillage or treatment interaction effect occurred for the R7 growth stage (data not shown). The highest relative ureide content was approximately 65% for the no fertilizer treatment with fixation as low as 42% for the 24 kg N ha^{-1} treatment (Figure 1). Although application of N fertilizer at planting decreased relative ureide (an estimate of N fixation) at beginning bloom (R1) there was an overall increase in biomass production, possibly indicating the importance of starter fertilizer in cool environmental conditions common in the northern Great Plains.

Table 2. Soybean ureide concentration by N source at beginning bloom (R1) and by tillage at beginning maturity (R7) treatment means, Brookings, SD 2000-2002.

	Ureide Concentration, mg kg^{-1}		
	2000	2001	2002
N Source	--	R1	--
AN	4024	2314	3360
UR	4693	2171	3791
Pr > F	0.0326	0.4678	0.0352
Tillage	--	R7	--
CT	2843	2583	4602
NT	3019	4096	6651
Pr > F	0.6553	0.0109	0.0565

CT – conventional tillage; NT – no-tillage; AN – ammonium nitrate; UR – urea

REFERENCES

Catalado, D.A., M. Haroon, L.E. Schrader, and V.L. Youngs. 1975. Rapid colorimetric determination of nitrate in plant tissue by nitration of salicylic acid. Comm. Soil Sci. Plant Anal. 6:71-80.

Harper, J.E. 1987. Nitrogen metabolism. *In* Soybean: Improvement, production and uses, 2nd Ed. Agron. Monogr. 16 p. 497-533. ASA, CSSA, and SSSA, Madison, WI.

Herridge, D.F., and M.B. Peoples. 1990. Ureide assay for measuring nitrogen fixation by nodulated soybean calibrated by ^{15}N methods. Plant Physiol. 93:495-503.

National Agricultural Statistics Service. 1993. Crop production 1992 summary. Cr Pr 2-1 (93). USDA, Washington, DC.

National Agricultural Statistics Service. 2003. Crop production 2002 summary. Cr Pr 2-1 (03). USDA, Washington, DC.

Patterson, T.G., R. Glenister, and T.A. LaRue. 1981. Simple estimate of ureides in soybean tissue. Anal. Biochem. 119:90-95.

Ritchie, S.W., J.J. Hanway, H.E. Thompson, and G.O. Benson. 1996. How a soybean plant develops. Iowa State Univ. of Sci. and Tech. Coop. Ext. Service. Ames, IA. Spec. Pub. 53.

SAS Institute. 1999. The analyst applications. Release 1st ed. SAS Inst., Cary, NC.

Schepers, J.S., D.D. Francis, and M.T. Tompson. 1989. Simultaneous determination of total C, total N and ^{15}N on soil and plant material. Commun. Soil Sci. Plant Anal. 20:949-959.

Starling, M.E., C.W. Wood, and D.B. Weaver. 1998. "Starter nitrogen" and growth habit effects on late-planted soybean. Agron. J. 90:658-662.

Tisdale, S.L., W.L. Nelson, J.D. Beaton, and J.L. Havlin. 1993. Soil fertility and fertilizers. 5th ed. MacMillian, New York.

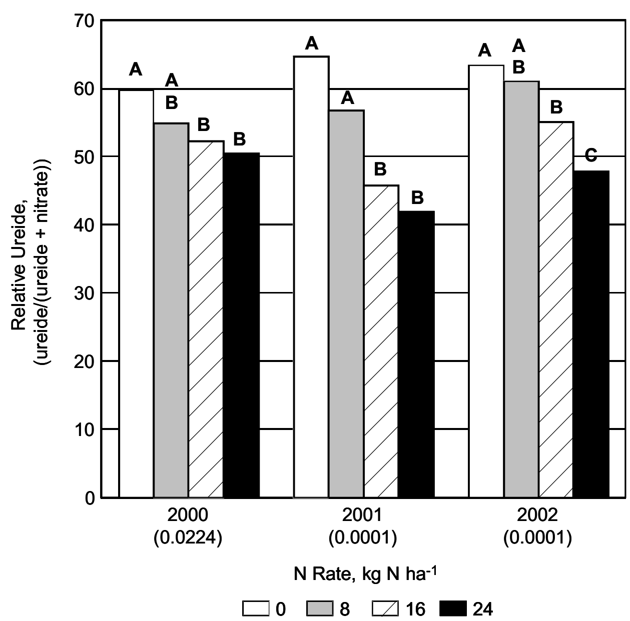

Figure 1. Relative ureide response to N rate for the R1 biomass sampling date averaged over tillage and N sources, Brookings, SD, 2000-2002. (Pr > F values listed in the figure represent the probabilities of a significant response to applied N).